Indian Institute of Space Science and Technology

Department of Space, Govt. of India
Thiruvananthapuram

Bachelor of Technology in

Computer Science and Engineering

(Data Science)

Curriculum and Syllabus

July 2025 Batch onwards

BTech in Computer Science and Engineering (Data Science)

Category	Category Code	Credit
Major Core+Elective	MC/ME	87-93
Holistic Enrichment Courses (Total)	HEC	30-33
Extra-Curricular Activities	HEC	5
Co-Curricular Activities	HEC	4
Vocational Courses	VC	7
Summer Internship	Internship	3
Minor Stream	MS	12-18
Research Project	RP	15
Total		157-160

BTech Computer Science and Engineering (Data Science)

Curriculum

Semester – I

Category Code	Title	L	T	P	C
MC	Computer Programming	2	0	0	2
MC	Introduction to Data Science	2	1	0	3
HEC	Materials Chemistry	3	0	0	3
MC	Calculus	3	0	0	3
HEC	Introduction to Social Science and Ethics	2	0	0	2
HEC	Communication Skills 1	1	0	2	2
VC	Programming Lab 1	0	0	4	2
VC	Basic Engineering Lab	1	0	2	2
HEC	Extracurricular activities	0	0	0	1
	Total	14	1	8	20

Semester II

Category Code	Title	L	T	P	C
MC	Data Structures	3	0	0	3
HEC	Physics	3	0	0	3
MC	Discrete Mathematics	3	0	0	3
MC	Programming Paradigms	3	0	0	3
HEC	Communication Skills 2	1	0	0	1
MC	Linear Algebra & Optimization	3	0	0	3
MC	Data Structures Lab	0	0	2	1
MC	Physics Lab	0	0	2	1
VC	Programming Lab 2	0	0	2	1
HEC	Extracurricular activities	0	0	0	1
	Total	16	0	6	20

Semester – III

Category	Title	L	T	P	C
MC	Electrical and Electronics Engineering	3	0	0	3
MC	Artificial Intelligence	2	0	2	3
MC	Algorithms	2	0	2	3
MC	Digital System Design	3	0	0	3
MC	Probability and Statistics	3	0	0	3
MC	Theory of Computation	2	1	0	3
VC	Digital System Design Lab	0	0	2	1
HEC	Extracurricular activities	0	0	0	1
		15	1	6	20

Semester – IV

Category	Title	L	T	P	C
MC	Computer Organization	3	0	0	3
MC	Signals and Systems	3	0	0	3
MC	Software Engineering	2	1	0	3
MC	Operating Systems	3	0	0	3
MC	Database Management Systems	3	0	0	3
HEC	Introductory Principles of Economics	2	0	0	2
MC	Operating Systems Lab	0	0	2	1
MC	Database Management Systems Lab	0	0	2	1
HEC	Extracurricular activities	0	0	0	1
HEC	Cocurricular activities	0	0	0	(1)
	Total	16	1	4	20+ (1)

Semester – V

Category	Title	L	T	P	C
MC	Machine Learning	3	0	0	3
MC	Computer Networks	3	0	0	3
HEC	Environmental Science and Engineering	2	0	0	2
HEC	Principles of Management and Entrepreneurship	2	1	0	3
ME	Major Elective 1	3	0	0	3
MS	Minor Stream Slot 1	3	0	0	3
MC	Computer Network Lab	0	0	2	1
MC	Machine Learning Lab	0	0	2	1
HEC	Extracurricular activities	0	0	0	1
HEC	Cocurricular activities	0	0	0	(1)
	Total	16	1	4	20+ (1)

Semester – VI

Category	Title	L	T	P	C
MC	Deep Learning	3	0	0	3
ME	Major Elective Slot 2	3	0	0	3
MC	Compiler Design	3	0	0	3
MS	Minor Stream Slot 2	3	0	0	3
MS	Minor Stream Slot 3	3	0	0	3
MC	Data Analytics and Visualization	3	0	0	3
MC	Compiler Design Lab	0	0	2	1
VC	Data Analytics and Visualization Lab	0	0	2	1
HEC	Cocurricular Activities	0	0	0	(1)
	Total	18	0	4	20+ (1)

Semester – VII

Category	Title	L	T	P	C
ME	Major Elective Slot 3	3	0	0	3
ME	Major Elective Slot 4	3	0	0	3
MS	Minor Stream Slot 4	3	0	0	3
HECE	HEC Elective Slot 1	3	0	0	3
MS/ME	Minor Stream Slot 5/Major Elective Slot 5	3	0	0	3
MS/ME/ HECE	Minor Stream Slot 6/Major Elective Slot 6/HEC Elective Slot 2 (optional)	3	0	0	3
Internship	Summer Internship and Training	0	0	0	3
HEC	Cocurricular activities	0	0	0	(1)
	Total	15-18	0	0	18-21 +(1)

Semester – VIII

Category	Title	Credit
RP	Research Project	15
HEC	Cocurricular activities	4
	Total	19

Elective Tracks	Credits
Data Science and Machine Learning	12-18
Information Security and Communication	12-18
Advanced Computer Systems	12-18

Major Electives

a. <u>Data Science and Machine Learning</u>

1. Reinforcement Learning
2. Computational Linguistics
3. Intelligent Robotics Algorithms
4. Computer Vision
5. An Introduction to Game Theory
6. Introduction to Digital Image Processing
7. Natural Language Processing
8. Large Language Models
9. Probabilistic Graphical Models
10. Topological Data Analysis
11. Cloud Computing
12. Bayesian Machine Learning
13. Graph Data Analysis
14. Advanced Kernel Methods
15. Advanced Machine Learning
16. Scalable Machine Learning
17. MLOps
18. AI Ethics
19. Big Data Analytics
20. Quantum Machine Learning
21. Quantum Deep Learning
22. Big Data Analytics in Atmospheric Science
23. Geospatial Data Science and Techniques
24. Data Driven Astronomy
25. Distributed Machine Learning
26. Internet of Things (IoT)
27. Explainable AI
28. AI in Healthcare

b. Information Security and Communication

1. Computer Security
2. Cybersecurity, Privacy & Ethics
3. Blockchain Application Development
4. Computational Geometry
5. Geographic Information Systems (GIS)
6. Quantum Communication and Cryptography

c. Advanced Computer Systems

1. Architecture of High-Performance Processors
2. Embedded System
3. Onboard Computers
4. Real-Time Operating Systems
5. Synthesis of Digital Systems
6. Software Engineering
7. Algorithms for Big Data
8. Advanced Algorithms
9. Information Retrieval
10. Cryptography
11. Parallel and Distributed Systems
12. Mobile Application Development
13. Blockchain Technology
14. Distributed Systems
15. Human-Computer Interaction (HCI)
16. Game Development
17. Quantum Computation
18. Graph Theory and Network Analysis
19. Advanced Database Systems

Syllabus

Semester I

Computer Programming (2 – 0 – 0) 2 credits

Introduction to Linux – introduction to programming – basic elements of a program, variables, values, types, assignment – expressions and control flow – iteration and loop design, arrays, for loop, functions, pointers, parameters, recursion – object-oriented paradigm, objects, classes, constructors, destructor, operator overloading, friend function, inheritance.

Text Books

1. Lippman, S. B., Lajoie, J., and Moo, B. E., C++ Primer, 5th ed., Addison-Wesley (2012).
2. Lafore, R., Object-Oriented Programming in C++, 4th ed., Sams Publishing (2001).

References

1. Cohoon, J. P. and Davidson, J.W., Programming in C++, 3rd ed., Tata McGraw-Hill, (2006).
2. Bronson, G., A First Book of C++, 4th ed., Cengage (2012).
3. Stroustrup, B., The C++ Programming Language, 3rd ed., Pearson (2005).

Introduction to Data Science (2-1-0) 3

Overview of Data Science, Data Handling with Python, Characteristics of Data, Statistical Description of Data, Data Visualization, Data Preprocessing, Basic Concepts of Machine Learning, K-Nearest Neighbors (KNN).

Textbooks

- Grus, J. (2019). *Data Science from Scratch: First Principles with Python* (2nd Edition). O'Reilly Media.
- McKinney, W. (2018). *Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython* (2nd Edition). O'Reilly Media.

References

1. Healy, K. (2018). *Data Visualization: A Practical Introduction*. Princeton University Press.
2. Ozdemir, S., & Susarla, D. (2017). *Feature Engineering Made Simple: Principles and Practices for Predictive Models*. Apress.
3. Bruce, P., & Bruce, A. (2020). *Practical Statistics for Data Scientists: 50 Essential Concepts*. O'Reilly Media.

Materials Chemistry (3-0-0) 3 Credits

Chemical Bonding and Intermolecular Forces: Ionic, covalent, metallic, and hydrogen bonding, van der Waals forces, dipole interactions, Influence on material properties.
Semiconducting Materials: Band theory: conductors, semiconductors, and insulators-Intrinsic and extrinsic semiconductors (n-type and p-type)- Materials: silicon, germanium, GaAs, perovoskites-Doping, defects, and their role in conductivity-Applications in ICs, transistors, solar cells, sensors
Polymers and Conducting Materials: Classification - Conducting polymers and Biodegradable polymers and their electronic applications
Nano and Smart Materials: Introduction to nano and smart materials and their properties-Carbon nanostructures: graphene, CNTs, Applications in sensors, electronics
Material Characterization: X-ray diffraction and Electron microscopy- Principles and Applications in material characterization
Batteries: Introduction to batteries: Li-ion batteries, solid-state batteries, Supercapacitors -Fuel cells: working principles and applications

Textbook:

1. *William D. Callister Jr. & David G. Rethwisch,* Materials Science and Engineering: An Introduction, 10th Ed., Wiley, 2019.

References:

1. *James F. Shackelford,* Introduction to Materials Science for Engineers, Pearson, 2015

2. Bradley D. Fahlman, Materials Chemistry, 3rd Ed., Springer 2018

3. Donald R. Askeland & Wendelin J. Wright, Fundamentals of Materials Science and Engineering

4. Guozhong Cao & Ying Wang, Nanostructures and Nanomaterials: Synthesis, Properties and Applications. World Scientific, 2011

Calculus (3-0-0) 3 Credits

Sequences and Series:
Limit of a sequence, monotone and Cauchy sequences and properties of convergent sequences, examples. Infinite series, positive series, tests for convergence and divergence, integral test, alternating series, Leibnitz test.

Differential Calculus:
Continuity and differentiability of a function of a single variable, statement of Rolle's Theorem, Lagrange's mean value theorem and applications.

Integral Calculus:
Definite Integrals as a limit of sums, Applications of integration to area, volume, surface area, Improper integrals

Functions of several variables:
Continuity and differentiability, Mixed partial derivatives, Local maxima and minima for function of two variables, Lagrange multipliers

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Textbooks:

1) Stewart, J Calculus: Early Transcendentals, 5th Edition Brooks/Cole, 2007
2) Sudhir R Ghorpade, Balmohan V. Limaye, A Course in Calculus and Real Analysis, Springer, 2006.

References:

1) Michael Spivak, Calculus,
Cambridge University Press, 2006.
2) Serge Lang, A First course in Calculus -
Springer-Verlag, 2000.

Introduction to Social Science and Ethics (2 – 0 – 0) 2 credits

Social Science: introduction to sociology, anthropology – social science research design and sampling. Ethics: professional and personal ethics – values & norms and human rights.

Text Books

- Lecture Notes

References

2. Perry, J. and Perry, E., Contemporary Society: An Introduction to Social Science, 11th ed., Allyn & Bacon (2005).
1. Giddens, A., Sociology, 5th ed., Wiley (2006).
2. Flyvbjerg, B., Making Social Science Matter, Cambridge Univ. Press (2001).
3. Singer, P., A Companion to Ethics, Wiley-Blackwell (1993).

HS111H Communication Skills 1 (1-0-2) 2 Credits

Module 1- Functional English

Conversation Skills: Asking questions, requests, doubts, engage in conversation, Different types

of Communication-verbal and non-verbal, body language

Module 2: Teaching Grammar

Grammar Games, Exercise

Module 3: Teaching Vocabulary

Language Games, Exercise

Module 4: Presentation Skills

Module 5: Role Plays, debates, extempores, group presentations

Textbook:

Babitha Marina Justin and Bhavya Thampy, The Grammar Edge: Write and Speak with Power and Precision, Vallaths Publications, 2025

References:

I . Alan Garner. Conversationally Speaking: Tested New Ways to Increase Your Personal and Social Effectiveness.

2. Mike Bechtle. Confident Conversation: How to Communicate Successfully in Any Situation

3. Ronald carter, Rebecca Hughes. Exploring Grammar in Context

4. Baker, Ann and S. Goldstein, Pronunciation Pairs, Cambridge Univ Press, Cambridge.2002.

5. S. Brown and D. Smith, Active Listening. Cambridge, CUP. 2004.

AA131V	Basic Engineering Lab (1-0-2)	2 Credits

Part A: Introduction to sketching- Introduction to Computer-Aided Drawing - Orthographic/ Isometric / sectional views- Development of surfaces.
Part B: Electrical wiring practice, Soldering practice**,** Identification and testing of electronic components, Circuit simulation using LT SPICE, PCB Design, PCB Fabrication, Soldering of components on PCB and testing.
Text Books / References:

1. Bhatt, N. D., Engineering Drawing: Plane and Solid Geometry, 50th ed., Charotar Publishing House (2010).
2. Varghese, P. I., Engineering Graphics with AutoCAD, 26th ed., VIP Publishers (2012).
3. Bethune, J. D., Engineering Graphics with AutoCAD 2014, Pearson Education (2014).
4. Lab Manual.

Semester – II

Data Structures (3 – 0 – 0) 3 credit

Big-O notation, Basic data types - Lists, Stacks, Queues, Trees, Abstract data types.

Advanced data types:Dictionaries, Binary search trees, Balanced search trees, B Trees, Hash tables - Chaining and Open Addressing, Heaps, Priority queues.

Graphs: Basic representation of Graphs, Breadth First search, Disjoint Set Data Structure and application to Minimum Spanning Tree.

Lab Implementation of some of the above data structures, Applications of data structures in solving computational problems.

Textbooks

(1) Introduction to Algorithms, T. H. Cormen, C. E. Leiserson, R. L. Rivest and C. Stein, MIT Press, 2009.
(2) Data Structures and Algorithms in Python, Michael T. Goodrich, Roberto Tamassia, Michael H. Goldwasser, John Wiley and Sons.

References

(1) Data Structures and Algorithms Using Python, Rance D. Necaise, Wiley.
(2) Data Structure and Algorithmic Thinking with Python - Narasimha Karumanchi, CareerMonk Publications.
(3) Art of Computer Programming Volumes 1-4, Addison-Wesley Professional, 2011.

Physics (3-0-0) 3 Credits

Mechanics:

Introduction to vectors: linear independence – completeness – basis – dimensionality– inner product – orthogonality – displacement – derivatives of a vector – velocity– acceleration – plane polar coordinates.

Electricity and Magnetism:

Electricity:Electrostatic potential and field due to discrete and continuous charge distributions, energy density in an electric field.

Magnetism:
Currents, Biot-Savert law, magnetic induction due to configurations of current-carrying conductors – energy density in a magnetic field, force on a charged particle in electric and magnetic fields,
electromotive force, Faraday's law of electromagnetic induction – self and mutual inductance, displacement current.

Modern Physics: relativity– introduction to quantum physics –atom model hydrogen atom. Photoelectric effect - blackbody radiation - wave matter duality - uncertainty principle - Compton scattering

Optics: nature of light – ray approximation in geometrical optics – reflection – refraction, Fermat's principle – dispersion – mirrors and lenses – aberrations – interference – diffraction –polarization –lasers.

Text books

1. Kleppner, D. and Kolenkow, R. J., An Introduction to Mechanics, 2nd ed., Cambridge Univ. Press (2013).
2. Griffith, D. J., Introduction to Electrodynamics, 3rd ed., Prentice Hall (1999).
3. Fundamentals of Physics, David Halliday, Jearl Walker, and Robert Resnick, Wiley, 2010.
4. Concepts of Modern Physics, Arthur Beiser, McGraw-Hill, 2009

Discrete Mathematics (2 – 0 – 2) 3 credits

Concept of Mathematical Proof, Logic, Proof by contradiction, Mathematical Induction, Constructive Proofs, Sets, Relations, Illustration of Proof Techniques in various mathematical topics.
Combinatorics: Basic Counting Principles, Inclusion-Exclusion Principle, Binomial/ Multinomial Coefficients, Bijections, Double Counting, Pigeon-Hole Principle, Recurrence Relations.
Introduction to Graphs: Basic terminology/Definitions, Isomorphism, Connectivity, Trees, Planarity.
Introduction to abstract algebra: Basics of Groups, Rings, Field, Polynomial Rings.

Textbooks:
(1) Kenneth Rosen, Discrete Mathematics and Applications, McGraw-Hill, 2019.
(2) Susanna S. Epp, Discrete Mathematics with Applications, Cengage Learning, 2018.

References:
(1) David Hunter, Essentials of Discrete Mathematics, Jones Bartlett Learning, 2015.
(2) Thomas Koshy, Discrete Mathematics with Applications, Elsevier Science, 2004.

Programming paradigms (3 – 0 – 0) 3 credit

Introduction to different paradigms of programming: Imperative - Object Oriented - Functional - Logic Imperative and Object-oriented Programming - Role of Types - Static and Dynamic Type Checking - Scope rules ; Grouping Data and operations, Information Hiding and Abstract Data Types, Objects, Inheritance, Polymorphism,Templates.
Functional Programming - Expressions, Evaluation, types, type systems, values and operations, function declarations, lexical scope, lists and programming with lists, polymorphic functions, higher order functions, Data abstraction.

Logic Programming - Review of predicate logic, clausal-form logic, logic as a programming language, Unification algorithm, Abstract interpreter for logic programs, Semantics of logic programs, Prolog
- arithmetic, recursion, cuts and negation, Real-life applications of Prolog. Prolog implementation in Scheme/Lisp.

Textbook:

Scott M L, Programming Language Pragmatics, 3rd Edn., Morgan Kaufmann Publishers, 2009

References:

1. Programming Languages: Design and Implementation (4th Edition), by Terrence W. Pratt, Marvin V. Zelkowitz, Pearson, 2000.
2. David A Watt, Programming Language Design Concepts, Wiley Dreamtech, 2004
3. Ghezzi C and M. Jazayeri, Programming Language Concepts, 3rd Edn, Wiley.1997
4. Kenneth C Louden, Programming Languages: Principles and Practice, 3rd Edn., Cengage Learning, 2011.

HS121H Communication Skills 2 (1 – 0 – 0) 1 credit

Module 1: Audience analysis and adaptation

Module 2: Technical writing formats and styles (e.g., reports, minutes, posters, proposals, manuals, instructions), Writing style and tone, Clarity, conciseness, and coherence, Introduction to Technical Writing: Document planning and organization

Module 3: Reading and appreciating stories, poems, essays, Comprehensive questions and answers, Listening and note taking video lectures

Module 4: short plays, individual presentations, group discussions, debates

References:

1. Buzan, Tony. Use Your Head, Guild Publishing, 1974.

2. G. Maugur, The English Language Laboratory Drills for Students of Science and Technology, Oxford, OUP. 2005.

3. Mc Carthy, Carter. Cambridge Grammar of English. Cambridge, CUP.2006

4. Yule, George. Oxford Practice Grammar. Oxford, OUP. 2006.

5. Anderson, Kenneth. Et al. Study Speaking. CUP, Cambridge.2004.

6. Freeman, Sarah. Written Communication in English. Orient Longman, Chennai. 2005.

7. Hancock, Mark. English Pronunciation in Use. CUP, UK. 2003.

8. Swales, J. M., & Feak, C. B. Academic writing for graduate students: Essential tasks and skills (Vol. 1). Ann Arbor, MI: University of Michigan Press. 2004.

9. Belcher, W. L.Writing your journal article in twelve weeks: A guide to academic publishing success. University of Chicago Press.2019

Linear Algebra and Optimization (3 – 0 – 0) 3 credits

Matrices, Linear equations, and solvability:
- Vector spaces
- Basis and dimension
- Linear transforms
- Similarity of matrices

Rank-Nullity theorem and its applications:
- Eigenvalues and eigenvectors
- Cayley-Hamilton theorem and diagonalization
- Inner-product spaces
- Gram-Schmidt process

Optimization:
Unconstrained optimization: Gradient descent and Stochastic gradient descent methods. Constrained optimization: Lagrange multiplier, Linear and dynamic programming, Bellman's principle of optimality.

Textbooks:
1) Elizabeth Meckes and Mark W. Meckes, Linear Algebra, Cambridge University Press, 2018.
2) Edwin K.P. Chong and Stanislaw H. Zak, Introduction to optimization, Wiley, 2013.

References:
1) Sheldon Axler, Linear Algebra Done Right, Springer, 2015.
2) Linear Algebra and Optimization for Machine Learning, Charu Aggarwal, Springer, 2020.
3) Linear Algebra and its Applications, 4th Edition, Gilbert Strang, Cengage India Private Limited; 2005.

Semester – III

Electrical and Electronics Engineering (3 – 0 – 0) 3 credits

Fundamentals of AC Power System: Introduction to Alternating Current – Basic concepts of AC
circuits – Behaviour of resistor, capacitor and inductor in AC circuits – concepts of reactance and impedance - Sinusoidal steady state analysis - Power in AC circuits. Three-phase systems –
Basic concepts of balanced three-phase systems– Power in three-phase systems.
Introduction to Electrical Machines: Basic concepts of transformers and rotating electrical machines.
Diode – clipping, clamping circuits, applications in rectifiers and power supplies. Amplifiers: BJT-Characteristics- DC analysis and AC analysis of BJT. Application of BJT as amplifiers/switch.

Introduction to operational amplifiers – characteristics/specifications and application to various circuits.
Digital circuits – Boolean logic – basic gates – truth tables – logic minimization using K maps –combinatorial and sequential circuits.
Text Books:
1. Boylestad, R. L. and Nashelsky, L., Electronic Devices and Circuit Theory, Pearson Education
(2003).
2. Mano, M. M., Digital Design, Prentice Hall (2002).
4. Same as Reference (Electrical Part)
References:
1. Vincent Del Toro : ‘Electrical Engineering Fundamentals’, Pearson Education
2. A.E.Fitzgerald, David E Higginbothom, Arvin Grabel: ‘Basic Electrical Engineering’, Tata McGraw-Hill
3. Hughes, E. : ‘Electrical and Electronic Technology’, Pearson Education.
4. Charles K Alexander, Mathew N O Sadiku: ‘Electric Circuits’
5. Fitzgerald, Kingsley, Umans, ‘Electric Machinery’, TMH 6. M.G.Say, ‘ Performance and Design of AC Machines

Artificial Intelligence (2 – 0 – 2) 3 credit

Introduction to Artificial Intelligence – Definition of AI; History and evolution of AI; Applications of AI in various domains.
Problem Solving and Search Algorithms — Problem formulation, state space search, uninformed strategies (BFS, DFS), informed strategies (A*, Greedy best-first), heuristic functions, adversarial search (Minimax, Alpha-beta pruning).

Information Retrieval –Overview of Information Retrieval systems; Role of search algorithms in information retrieval; Indexing and document representation; Evaluation metrics for information retrieval; Applications in search engines and databases.
Intelligent Agents – Definition and characteristics of intelligent agents; Types of intelligent agents: simple reflex, model-based, goal-based, utility-based; Agent architecture and functionality; Learning methods for intelligent agents; Case studies of intelligent agents in real-world applications.
Multi-Agent Systems -Communication among agents, cooperation and coordination, distributed decision-making, game-theoretic foundations, applications in collaborative environments and traffic systems.

Natural Language Processing (NLP) Basics – Introduction to NLP and its significance; Text preprocessing techniques; Tokenization, stemming, and lemmatization; Basic syntactic parsing and part-of-speech tagging; Introduction to sentiment analysis and language models; Applications of NLP in chatbots and virtual assistants.
Robotics Basics – Introduction to Robotics and its relation to AI; Components of a robotic system (sensors, actuators, controllers); Basic robot kinematics and motion planning; Introduction to robotic perception; Case studies of AI applications in robotics (e.g., industrial robots, autonomous vehicles).
Ethics in AI – Importance of ethical considerations in AI; Fairness, accountability, and transparency; Bias in AI systems; Privacy and data protection; Responsible AI and regulatory frameworks; Case studies highlighting ethical challenges in AI.
References

1. Stuart Russell and Peter Norvig, *Artificial Intelligence: A Modern Approach*, 4th Edition, Pearson, 2021.
2. Christopher D. Manning, Prabhakar Raghavan, and Hinrich Schütze, *Introduction to Information Retrieval*, Cambridge University Press, 2008.
3. Robin R. Murphy, *Introduction to AI Robotics*, 2nd Edition, MIT Press, 2019.
4. Michael Wooldridge, *An Introduction to MultiAgent Systems*, 2nd Edition, Wiley, 2009.
5. Virginia Dignum, *Responsible Artificial Intelligence: How to Develop and Use AI in a Responsible Way*, Springer, 2019.

Algorithms (2 – 0 – 2) 3 credit

Algorithmic Design Paradigms, Divide and Conquer, Analysis for Divide and Conquer, Sorting algorithms, Greedy Algorithms, Dynamic Programming, Graph Algorithms (DFS, BFS, Topological sort, Spanning Trees, All pair shortest path, Matching Max flow)

Text Books

(1) T. H. Cormen, C. E. Leiserson, R. L. Rivest and C. Stein, Introduction to Algorithms, MIT Press, 2009.
(2) Kleinberg and Tardos, Algorithmic Design, Pearson, 2013.

References:

(1) G. T. Heineman, G. Pollice, S. Selkow, Algorithms in a Nutshell, O'Reilly Media, 2008.
(2) Narasimha Karumanchi, Data Structure and Algorithmic Thinking with Python - CareerMonk Publications, 2015.
(3) Art of Computer Programming Volumes 1-4, Addison-Wesley Professional, 2011.

Digital Systems Design (3 – 0 – 0) 3 credit

Boolean Algebra, standard representation and Minimization Procedures. Logic families, combinational circuits, asynchronous and synchronous sequential circuits, Memories, PROMs AND PLAs. Introduction to VLSI systems- CMOS logic- MOS transistor theory- Layout design rules- Circuit characterization and performance estimation- Circuit simulation- Combinational and sequential circuit design- Static and dynamic CMOS gates- Memory system design- Design methodology and tools-HDL. Design of FPRG, Complex CMOS design.

Textbooks:

1. Morris Mano, Digital Design, 4th ed., Prentice-Hall of India, 2006.
2. John.F.Wakerly , Digital Design Principles and Practice, 3rd edition, Pearson Education, 1990.

References:

1. William I. Fletcher, An Engineering Approach to Digital Design, Prentice-Hall of India, 1980.
2. T.L. Floyd, Digital Fundamentals, Charles E. Merrill publishing Company , 1982.
3. R.L. Tokheim, Digital Electronics- Principles and Applications, Tata McGraw Hill, 1999.
4. R.P . Jain, Modern Digital Electronics, Tata McGraw Hill, 1999.
5. N. Weste and D. Harris, CMOS VLSI Design: Circuits and Systems Perspective, Addison Wesley , 2004.
6. Wayne Wolf, Modern VLSI Design, Prentice Hall,1998.
7. Peter J. Ashenden, The Designer's Guide to VHDL, Harcourt Asia private Limited & Morgan Kauffman, 1996.
8. Douglas A. Pucknell and Kamran Eshraghian, Basic VLSI Design Systems and Circuits, Prentice Hall of India, 1993.

Probability and Statistics (3 – 0 – 0) 3 credits

Probability Theory: Elementary concepts on probability – axiomatic definition of probability – conditional probability – Bayes' theorem – random variables – standard discrete and continuous distributions – moments of random variables – moment generating functions – multivariate random variables – joint distributions of random variables – conditional and marginal distributions – conditional expectation – distributions of functions of random variables – t and $\chi 2$ distributions – Schwartz and Chebyshev inequalities – weak law of large numbers for finite variance case – central limit theorem for iid finite variance case.
Statistics: Elementary concepts on populations, samples, statistics – sampling distributions of sample mean and sample variance – point estimators and its important properties – point estimator for mean and variance and proportion – confidence interval for sample mean – tests of hypotheses Chi-squared test of goodness of fit.
Textbooks
1. Walpole, R. E., Myers, R. H., Myers, S. L., and Ye, K., Probability & Statistics for Engineers & Scientists, 9th ed., Pearson Education (2012).
2. Jain, M. K., Iyengar, S. R. K., and Jain, R. K., Numerical Methods for Scientific and Engi- neering Computation, 4th ed., New Age International (2005).
References
1. Johnson, R. A., Miller & Freund's Probability and Statistics for Engineers, 6th ed., Prentice Hall (2000).
2. Milton, J. S. and Arnold, J. C., Introduction to Probability and Statistics: Principles and Applications for Engineering and the Computing Sciences, 4th ed., McGraw Hill (2002).
3. Ross, S. M., Introduction to Probability and Statistics for Engineers and Scientists, 3rd ed., Academic Press (2004).
4. Hogg, R. V. and Tanis, E. A., Probability and Statistical Inference, 7th ed., Prentice Hall (2005).
5. Larsen, R. J. and Marx, M. L., An Introduction to Mathematical Statistics and Its Applications, 4th ed., Prentice Hall (2005).
6. Conte, S. D. and de Boor, C., Elementary Numerical Analysis, 3rd ed., TMH (2005).
7. Krishnamurthy, K. V., Numerical Algorithms, Affiliated East-West Press (1986).

Theory of Computation (3 – 0 – 0) 3 credit

Introduction: Notion of formal language. Language membership problem, why this is taken as the central problem of the subject.
Finite automata and regular expressions: DFA, NFA (with and without transitions), their equivalence. Proof that FAs recognize, and regular expressions denote the same class of languages, viz., regular languages.
Properties of regular languages: Pumping lemma and its use to prove non-regularity of a language, closure properties of class of regular languages, decision properties: converting among representations, testing emptiness, etc. Minimization of DFAs, Myhill-Nerode theorem.
Context-free grammars and languages: Derivation, parse trees. Language generated by a CFG. Eliminating useless symbols, -productions, unit productions. Chomsky normal form.

Pushdown automata: Definition, instantaneous description as a snapshot of PDA computation, notion of acceptance for PDAs: acceptance by nal states, and by empty stack; the equivalence of the two notions. Proof that CFGs generate the same class of languages that PDAs accept.
Properties of context-free languages: Pumping lemma for context-free languages and its use to prove a language to be not context-free. Closure properties of the class of context- free languages. CYK algorithm for CFL membership, testing emptiness of CFLs.
Turing machines: Historical context, informal proofs of undecidability. Definition of TM, instantaneous description as a snapshot of TM computation, notion of acceptance. Robustness of the model. Church-Turing hypothesis.
Undecidability: Definitions of r.e. and recursive languages. Turing machine codes, the diagonalization language and proof that it is not r.e. Universal Turing machine. Universal language, its semi-decidability. Reducibility and its use in proving undecidability. Rices theorem. Undecidability of Posts correspondence problem.
Intractability: Motivation for the notion. The class P as consensus class of tractable sets. Classes NP, co-NP. Polynomial time reductions. NP-completess, NP-hardness. Cook-Levin theorem. Mention about boundary of tractability: 2SAT vs. 3SAT, 2D matching vs. 3D matching. Some NP-completeness proofs: vertex cover, clique, independent sets, Hamiltonian graphs, subset-sum, set cover.

Books And References:

1. J Hopcroft, JD Ullman, R Motwani, Introduction to Automata Theory, Languages and Computation, 3rd Ed., Pearson, 2008.
2. M Sipser, Introduction to the Theory of Computation, 2nd Ed., Thomson, 2005.
3. M Sipser, Theory of Computation, Brooks-Cole, 2008.

Digital System Design Lab (1-0-2) 2 Credits

1. Design and hardware implementation of:
    a. 2-bit Adder/Subtractor with XOR as well as NAND gates,
    b. 4:1 Multiplexer using universal gates and realization of Full Adder using Multiplexers,
    c. BCD Adder using two binary adders (IC based) and other gates,
    d. 3:8 Decoder and realization of Full Adder
2. Realization of R-S, D and J-K latches and D Flip-Flop
3. Realization of Mod-8 Up-Down Ripple Counter
4. Realization of synchronous Mod-3 and Mod-2 counters
5. Realization of higher Mod counter by cascading lower Mod counters PART II: Digital System Design using HDL and EDA
6. Modeling different types of gates:
    (a) 2-input NAND (b) 2-input OR gate (c) 2-input NOR gate (d) NOT gate
    (e) 2-input XOR gate (f) 2-input XNOR gate
7. Modeling (a) Half-adder
    (b) Full-adder
8. Modeling a “D flip-flop”
9. Modeling a “D Latch”
10. Modeling a (a) 2-to-1 Multiplex (b) 2-to-4 Decoder (c) Tri-State Buffer

11. Modeling a 4-to-1 Multiplexer
12. Modeling a 4-bit PARALLEL ADDER
13. Modeling a 4-bit adder-subtractor circuit

Semester IV

Computer Organization (3 – 0 – 0) 3 credits

Introduction to computer organization: Structure and function of a computer- Processing unit: Characteristics of CISC and RISC processors- Performance of a processing unit. Memory subsystem : Memory hierarchy- Main memory unit- Internal organization of a memory chip - Organization of a main memory unit- Error correction memories- Interleaved memory units- Cache memory unit- Concept of cache memory- Mapping functions- organization of a cache memory unit- Fetch and Write mechanisms- Memory management unit- Concept of virtual memory- Address translation- hardware support for memory management. Input / Output subsystem: Access of I/O devices- I/O ports.- I/O control mechanisms- Program controlled I/O- Interrupt controlled I/O- DMA controlled I/O- I/O interfaces- System buses- peripherals-Terminals- Video displays- Magnetic storage disks- magnetic tapes- CD ROMs. High-Performance processors: Instruction pipe lining- Pipe line- Hazards- Super scalar processors-Performance considerations. Multi processor systems: Shared memory systems- Interconnection networks- Caches in multi processor systems.

Textbook/ References:
1. Tanenbaum A.S., Structured computer organization, 4th edition, PHI, 1999.
2. Hayes, J.P , Computer architecture and Organisation, McGraw Hill, 1998.
3. J. L. Hennessy, D. A. Patterson, Computer Architecture: A Quantitative Approach, Morgan Kaufmann Publishers, 2017.

Signals and Systems (3 – 0 – 0) 3 credits

Classification of signals and systems, Types of signals, Transformation of independent variable, Periodic signals and Periodicity , Types of systems, Analysis of Continuous Time Signals and LTI systems: Convolution, Impulse response, Trigonometric and exponential Fourier series, Eigen functions of LTI systems, Fourier Transform, Magnitude and Phase Spectra, Properties of Fourier Transform, Laplace Transform, Region of Convergence, Properties, Linear Constant coefficient Differential Equations, State Space Matrix for continuous time systems.
Anlaysis of Discrete Time Signals and LTI DT systems: Periodicity , Discrete Convolution, DFT, Properties, Z Transform, ROC, Properties, Difference Equations, State variable equation and

matrix, some applications – signal processing, communication, control systems etc.

Textbooks:
1. R.F. Ziemer, W.H. Tranter and D.R. Fannin, Signals and Systems- Continuous and Discrete, Prentice Hall, 2006.
2. B.P . Lathi, Linear Systems and signals, 2nd edition, Oxford University Press, 1998.
3. Simon Haykin, Barry Van V een, Signals and Systems, John Wiley and Sons (Asia) Private Limited, 2005.
4. A.V . Oppenheim, A.S. Willsky and I.T. Young, Signals and Systems, Prentice Hall, 2006.

References:
1. Douglas K. Lindner, Introduction to Signals and Systems, Mc-Graw Hill International,1999.
2. Robert A. Gabel, Richard A. Roberts, Signals and Linear Systems, John Wiley and Sons (SEA) Private Limited, 1995.
3. M. J. Roberts, Signals and Systems- Analysis using Transform methods and MATLAB, Tata McGraw Hill, 2003.
4. J. Nagrath, S. N. Sharan, R. Ranjan, S. Kumar, Signals and Systems, Tata McGraw Hill, New Delhi, 2001.
5. Ashok Ambardar, Analog and Digital Signal Processing, 2nd Ed., Brooks/ Cole Publishing Company , 2006.
6. A. Papoulis, Circuits and Systems: A Modern Approach, HRW, 1980.
7. B.P . Lathi, Signal Processing and Linear Systems, Oxford University Press, 1998

Software Engineering (2 – 1 – 0) 3 credits

Software development lifecycle. Life Cycle models. Process models. Requirements specifications. Basic software architecture. Basics of software design. Introduction to UML: Class and Interaction Diagrams, Design patterns in software. Procedural design methodology, Software implementation. Testing, verification and validation. Static analysis. Introduction to software model checking. Software metrics. Software project management.

Textbooks And References:

1. Ian Somerville, Software Engineering, 10th Ed., Pearson, 2015.
2. Pankaj Jalote, Software Engineering: A precise approach, Wiley 2010
3. C Ghezzi, M Jazayeri, D Mandrioli, Fundamentals of Software Engineering, 2nd Ed., Prentice-Hall, 2002.
4. RN Taylor, N Medvidovic, EM Dashofy, Software Architecture: Foundations, Theory and Practice, John Wiley, 2009.
5. Roger S Pressman, Software Engineering: A Practitioner’s Approach, McGrah-Hill Higher Education, 2020

Operating Systems (3 – 0 – 0) 3 credits

Introduction: review of computer organization, introduction to popular operating systems like UNIX, Windows, Android, etc., OS structure, system calls, functions of OS, evolution of OSs.
Computer organization interface: using interrupt handler to pass control between a running program and OS.
Concept of a process: states, operations with examples from UNIX (fork, exec) and/or Windows. Process scheduling, interprocess communication (shared memory and message passing), UNIX signals.
Threads: multithreaded model, scheduler activations, examples of threaded programs.
Scheduling: multi-programming and time sharing, scheduling algorithms, multiprocessor scheduling, thread scheduling (examples using POSIX threads).
Process synchronization: critical sections, classical two process and n-process solutions, hardware primitives for synchronization, semaphores, monitors, classical problems in synchronization (producer-consumer, readers-writer, dining philosophers, etc.).
Deadlocks: modeling, chararcterization, prevention and avoidance, detection and recovery.
Memory management: with and without swapping, paging and segmentation, demand paging, virtual memory, page replacement algorithms, working set model, implementations from operating systems such as UNIX, Windows. Current Hardware support for paging.
Secondary storage and Input/Output: device controllers and device drivers, disks, scheduling algorithms, file systems, directory structure, device controllers and device drivers, disks, disk space management, disk scheduling, NFS, RAID, other devices. operations on them, UNIX FS, UFS protection and security, NFS.
Protection and security: Illustrations of security model of UNIX and other OSs. Examples of attacks.
Epilogue: Pointers to advanced topics (distributed OS, multimedia OS, embedded OS, real-time OS, OS for multiprocessor machines).

1. Abraham Silberschatz, Peter B. Galvin, Greg Gagne, Operating System Concepts, 8th Ed., John Wiley, 2008.
2. William Stallings, Operating Systems: Internals and Design Principles. Prentice-Hall, 6th Ed., 2008.
3. AS Tanenbaum, Modern Operating Systems, 3rd Ed., Pearson, 2009.
4. AS Tanenbaum, AS Woodhull, Operating Systems Design and Implementation, 3rd Ed., Prentice Hall, 2006.
5. M. J. Bach. Design of the Unix Operating System, Prentice Hall of India, 1986.

Database Management Systems (3 – 0 – 0) 3 credits

Database system architecture: Data Abstraction, Data Independence, Data Definition and Data Manipulation Languages.
Data models: Entity-relationship, network, relational and object oriented data models, integrity constraints and data manipulation operations.
Relational query languages: Relational algebra, tuple and domain relational calculus, SQL and QBE.
Relational database design: Domain and data dependency, Armstrongs axioms, normal forms, dependency preservation, lossless design.
Query processing and optimization: Evaluation of relational algebra expressions, query equivalence, join strategies, query optimization algorithms.
Storage strategies: Indices, B-trees, hashing.
Transaction processing: Recovery and concurrency control, locking and timestamp based schedulers, multiversion and optimistic Concurrency Control schemes.
Advanced topics: Object-oriented and object relational databases, logical databases, web databases, distributed databases, data warehousing and data mining. Recent trends in DBMS.
Database schema design, database creation, SQL programming and report generation using a popular RDBMS like ORACLE/MySQL/Postgresql.
Students are to be exposed to front end development tools, ODBC and JDBC calls from application programs, internet based access to databases and database administration.

Textbooks:
1. Abraham Silberschatz, Henry Korth, and S. Sudarshan, Database System Concepts, McGrawHill
2. J. D. Ullman, Principles of Database Systems, Galgoti
3. R. Elmasri and S. Navathe, Fundamentals of Database Systems Addison-Wesley

HS223 Introductory Principles of Economics (2 – 0 – 0) 2 credits

Module 1: ***Exploring the subject matter of Economics***

What is Economics? Definitions – Importance of Economics for Engineers – Schools of thought The Economic Problem – Scarcity and Choice – Resource allocation – the question of What to produce, How to Produce and How to Distribute Output – its nature and Importance in developing countries – Economic Systems – Basics of Capitalism, Socialism, Mixed Economy, Market Economy and Third World Economies.

Is Economics a Science? Distinction between Micro and Macro Economics.

Module 2: ***Principles and Concepts of Micro Economics***

Determinants of individual demand/supply, Demand/Supply schedule and demand/supply curve, Market versus individual demand/supply, Shifts in the demand/supply curve,

Demand and Supply together, How Prices allocate resources - Equilibrium - Elasticity - Consumer equilibrium – Marginal utility – Consumer surplus - Production – factors of production, production function – Laws – TR, AR, MR- Costs – TC, AC, MC, OC – Variable Vs Fixed costs – Short Run Vs Long Run costs - Markets – Perfect competition, Monopoly, Monopsony, Oligopoly.

Module 3: *Basics of Macro Economics*

The roots of macroeconomics, macroeconomic concerns, the role of government in the Macro economy, the components of the macro economy, the methodology of macroeconomics. Concepts of GNP, GDP, NNP, NDP and National Income – Personal Income and Disposable Income – Nominal and Real GDP – Limitations – Black Economy Concept of Inflation, Deflation, Methods of calculation – Classical Vs Keynesian Economics – Full employment Vs Under employment equilibrium – Globalization – Global Financial Crisis.

Module 4: *Economic Problems and Policies*

Developing Countries Vs Developed Countries, differences, characteristics, LDC's. Meaning of Development

– Development Vs Growth, Measuring development - Problems of Growth – lessons and controversies, Indian situation - Poverty and Inequality – vicious circle of poverty – Recent BPL controversy - Population and Development – Demographic transition theory – optimum population - Agriculture, Industry and development - Balance of Payments – Closed and Open Economy – LPG- Planning and Growth – Global Financial Crisis.

A research report.

Textbooks

1. Samuelson, Paul A and William D Nordhaus "Economics" (17th Edition), Mc Graw Hill.
2. Dewett K K "Modern Economic Theory" S Chand
1. Thirlwall, A P "Growth and Development with Special Reference to Developing Economies" Palgrave.

References

1. Ackley, Gardner "Macroeconomic Theory" Surjeet PublicationsKoutsoyiannis, A "Modern Micro Economics" Palgrave Macmillan
1. Black, John "Dictionary of Economics" Oxford University Press.
1. Meir, Jerald M and James E Rauch, "Leading Issues in Economic Development" (7 th Edition) Oxford University Press.
2. Todaro, Michael P and Steven C Smith "Economic Development" Pearson Education Ltd.
3. Govt. of India, "Economic Survey" (latest survey) Ministry of Finance.
4. The Hindu, News paper, Daily.
5. Connor, David E "The Basics of Economics" Greenwood Press.

Semester – V

Machine Learning	(3 – 0 – 0) 3 credits

Introduction to Machine Learning: Capacity, overfitting and underfitting, regularization techniques, hyperparameters, bias and variance, PAC model, Rademacher complexity, growth function, VC-dimension, model evaluation and selection, ML frameworks in python.
Supervised Learning: Concepts of classification and regression, linear and ridge regression, perceptron, k-nearest neighbor classifiers, decision tree, logistic regression, naive Bayes, Gaussian discriminant analysis, linear models for classification and regression, multi-class classification techniques.
ML Architectures: Kernel methods: SVM, Neural networks: multilayer perceptron, Graphical Models: Hidden Markov Models (HMM).
Unsupervised Learning: Cluster analysis, k-means, hierarchical clustering, spectral clustering, mixture modeling, self-organizing maps, independent component analysis (ICA).
Dimensionality Reduction Methods: Supervised feature selection, principal component analysis.
Ensemble Learning: Bagging, boosting, AdaBoost, random forest.
Data Preprocessing: Outlier mining; imbalance problem.
Learning Techniques: Introduction to semi-supervised learning, reinforcement learning, transfer learning, active learning.

References

1. Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep Learning. MIT Press. ISBN: 978-0262035613.
2. Murphy, K. P. (2012). Machine Learning: A Probabilistic Perspective. MIT Press. ISBN: 978-0262018029.
3. Bishop, C. M. (2006). Pattern Recognition and Machine Learning. Springer. ISBN: 978-0387310732.
4. Hastie, T., Tibshirani, R., & Friedman, J. (2009). The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Springer. ISBN: 978-0387848570.
5. Han, J., Kamber, M., & Pei, J. (2011). Data Mining: Concepts and Techniques (3rd Edition). Morgan Kaufmann.

Computer Networks (3 – 0 – 0) 3 credits

Introduction to Computer Networks: History of Evolution of the Internet, Network Topology , Layered Protocol Stack, Point-to - point and broadcast communications, LAN, WAN, MAN, and the Internet. Delay analysis in circuit switching, message switching, and packet switching. Queuing models.
Application Layer Protocols: Responsibilities of application layer. Domain Name System, services offered by DNs, Hyper Text Transfer Protocol (HTTP), File Transfer Protocol (FTP), SMTP/E-mail Applications, V oice over IP , and P2P protocols. Transport Layer protocols: Transport layer: Responsibilities of the transport layer, transport protocol design, Congestion control, flow control, reliability , quality of service, TCP , UDP , (optional SCTP) protocols, and
throughput analysis.
Network Layer Protocols: Responsibilities of network layer. Routing process, Link state and distance vector protocols, time complexity of algorithms, routing metrics, Routing in the Internet, RIP , BGP , Addressing in the Internet, IPV4, IPV6.
Data link layer: Objectives of the data link layer. Sublayers in Data link layer. Framing. Medium access protocols: –Aloha, CSMA and its variations, Ethernet; Token Ring; Framing and Error Control Techniques; Throughput analysis of MAC protocols. Error Control Techniques; Flow control; Bridges, Repeaters, Switches and the spanning tree protocol. Software defined networks. Recent advances in networks.
T ext Books:
1. James Kurose and Keith Ross, Computer Networking: A Topdown Approach, 6th Edition, Pearson Education, 2012.
2. Douglas E. Comer, Internetworking with TCP/IP, Pearson Education India, 2015
References:

1. Andrew S. Tannenbaum and D. J. Wetherall, Computer Networks, PHI, 5th Edition, 2010
2. William Stallings, Data and Computer Communications, 10th Edition, Pearson Education, 2013
3. Dimitry Bertsakes and Robert Gallager, Data Networks, 2nd edition, Pearson Education, 1992.
4. TCP/IP Illustrated: The protocols, Fall Kevin R., Stevens W. Richard, Addison Wesley Professional, 2011

HS321 Environmental Science and Engineering (2 – 0 – 0) 2 credits

Awareness of the impact of environment on quality of life – natural resources – biological systems – bio-geo chemical cycles – chemical processes; water treatment operations, water sampling, storage, quality measurement – oxygen demand – detection of pollutants

– current environmental issues; pollutants, global warming, causes and consequences, air pollution, organic and inorganic air pollutants, smog-acid mine drainage, accumulation of salts in water– soil formation; micro and macro nutrients in soil, pollutants in soil – green chemistry: an alternative tool for reducing pollution – engineering interventions; flow sheets, waste minimization, e-waste management, ASP, reverse osmosis, trickling filter – environmental management; solid, liquid waste management, hazardous wastes, ISO standards – Kyoto protocol, Montreal protocol, Euro norms.

Text Books

1. Rao, V., Textbook of Environmental Engineering, Prentice Hall of India (2002).

References

1. Baird, C. and Cann, M., Environmental Chemistry, 3rd ed., W. H. Freeman and Company (2005).

2. Manual on Water Supply and Treatment, CPHEEO, Ministry of Urban Development, GOI (1999).

3. Manual on Sewerage and Sewage Development, CPHEEO, Ministry of Urban Development, GOI (1993).

4. Hauser, B. A., Practical Hydraulics Hand Book, Lewis Publishers (1991).

5. Hammer, M. J., Water and Wastewater Technology, Regents/Prentice Hall (1991).

6. Sharma, J. P., Comprehensive Environmental Studies, Laxmi Publications (2004).

7. Garg, S. K., Environmental Engineering (vol. 1 and 2), Khanna Publishers (2004).

8. Kiely, G., Environmental Engineering, McGraw-Hill (1997).

9. Bharucha, E., Textbook of Environmental Studies, University Grants Commission (2004).

10. Vanloon, G. W. and Duffy, S. J., Environmental Chemistry: A Global Perspective, Oxford Univ. Press (2000).

HS312H Principles of Management & Entrepreneurship (2 – 1 – 0) 3 credits

Industrial Management: Development of Management thought-Management Functions – planning – organizing – power and authority-organization structures – span of control – delegation, leadership, directing and controlling-management by objectives-forecasting models.

Project Management: Characteristics of R&D projects – Development of project network – project representation – project scheduling – linear time – cost trade-offs in projects-project monitoring and control with PERT – resource leveling-break even analysis – application of linear programming in resource allocations-simplex method, assignment of people to projects-man power planning, quality of work life, job rotation, job enrichment.

Entrepreneurship: Qualities and characteristics of an entrepreneur-–Classification of Entrepreneurs–Creativity and Innovation- New Product Development- Understanding the business opportunities and needs of customers- From idea to start-ups- Preparation of

business plans, India as a Start-up Nation, National Entrepreneurial Culture, Entrepreneurship and Employment, Start-up Case Studies

Text Book and References

1. Koontz H., O Donnel, C., and Weihrich, H., Essentials of Management, McGraw-Hill (2018).
2. Prasad, L.M., Principles and Practice of Management, Sultan Chand and Sons (2018).
3. Mazda F., Engineering Management, Prentice Hall (1997).
4. Gido, J. and Clements, J. P., Successful Project Management, 2nd ed., South-Western College
5. Publishing (2003).
6. Daft, R.L., and Uppal, N. Understanding the theory and design of organizations, Centage Learning India Pvt Ltd (2020).
7. Ravi,V., Industrial Engineering and Management, PHI Learning Private Limited, New Delhi (2015).
8. Gupta.M.P and Khanna.R.B. Quantitative Techniques for decision making, PHI Learning Private Limited, New Delhi (2011).
9. Rai, R Entrepreneurship, Oxford University Press, 2011.
10. Khandwalla, P.N. Lifelong Creativity, Tata Mc Graw Hill, 9th Edition, 2011.
11. Rastogi, N., Managing creativity for Corporate Excellence, Macmillan Publications, 2011.

Semester – VI

Deep Learning	(3 – 0 – 0) 3 credits

Introductory Concepts: Perceptron, multilayer perceptron, deep learning as composite functions, Loss functions, activation functions, backpropagation, deep learning frameworks (e.g., TensorFlow, PyTorch, Keras).
Optimization Algorithms and Regularization Techniques; Convolutional Neural Networks (CNNs): architecture, pretrained models, transfer learning, backpropagation; Sequence Modeling: Recurrent Neural Networks (RNNs), Long Short-Term Memory (LSTMs), Gated Recurrent Units (GRUs), attention mechanisms, and their backpropagation; Encoder-decoder models.
Unsupervised Learning: Autoencoders, including denoising autoencoders and sparse autoencoders.
Generative Models: Generative Adversarial networks (GANs), variational autoencoders (VAEs), deep generative models combining GANs and VAEs.
Attention Mechanism: Soft vs. hard attention, global vs. local attention, self-attention, Transformers (key, value, query), multi-head attention.
Data-Efficient and Resource-Efficient Learning: Few-Shot Learning, zero-shot learning, model pruning, model compression, neural architecture search (NAS).
Fusion of Deep Learning with Graphical Models and Reinforcement Learning: Restricted Boltzmann Machines (RBMs), deep belief net, deep reinforcement learning.
Graph Neural Networks: Basics, spectral and spatial graph convolutional networks (GCNs).
Advanced Topics: Latest trends (e.g., self-supervised learning, applications of transformers beyond NLP), ethical considerations: fairness in AI (bias, transparency, implications of AI decisions on society).

References:

1. Chollet, F. (2017). Deep Learning with Python. Manning Publications.
2. Nielsen, M. (2015). Neural Networks and Deep Learning. Determination Press.
3. Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep Learning. MIT Press. ISBN: 978-0262035613.

Compiler Design	(3 – 0 – 0) 3 credits

Lexical Analysis: Techniques for tokenizing input code. Syntax Analysis: Parsing strategies to understand code structure. Semantic Analysis: Ensuring code adheres to language rules. Intermediate Code Generation: Translating source code into an intermediate representation. Optimization: Enhancing the intermediate code for performance. Code Generation: Producing machine-level code for execution. Run-Time Systems: Managing resources during program execution.

Textbooks:

1. A. V. Aho, M. S. Lam, R. Sethi, and J. D. Ullman, Compilers: Principles, Techniques, and Tools, 2nd ed. Boston, MA, USA: Pearson/Addison Wesley, 2006.

2. K. D. Cooper and L. Torczon, Engineering a Compiler, 2nd ed. San Francisco, CA, USA: Morgan Kaufmann, 2011.

3. A. W. Appel, Modern Compiler Implementation in C, Cambridge, U.K.: Cambridge University Press, 1998.

4. S. S. Muchnick, Advanced Compiler Design and Implementation, San Francisco, CA, USA: Morgan Kaufmann, 1997.

5. T. Parr, The Definitive ANTLR 4 Reference, 2nd ed. Raleigh, NC, USA: Pragmatic Bookshelf, 2013.

6. M. L. Scott, Programming Language Pragmatics, 4th ed. Burlington, MA, USA: Morgan Kaufmann, 2015.

6.

Data Analytics and Visualization (3 – 0 – 0) 3 credits

Information Visualization, Visual Display of Quantitative Information, Power of Representation, Data-Ink and Graphical Redesign, Data Density, Interactive Data Visualization for the Web. Scalable, Versatile and Simple Constrained Graph Layout, Visualization of Adjacency Relations in Hierarchical Data

Theory, Experimentation and the Application to the Development of Graphical Models, Layering Interactive Dynamics for Visual Analysis, Animated Transitions in Statistical Data Graphics Effectiveness of Animation in Trend Visualization

Cartogram: Value-by-Area Mapping. Cartography Thematic Map Design and Adaptive Composite Map Projections. Information Visualization for Search Interfaces, Information Visualization for Text Analysis, Supporting Asynchronous Collaborative Information Visualization, Designing for Social Data Analysis,

Tool based Visualization of different data, Visual analytics, Dashboard development, Exploratory visualization.
Google page ranking, ICA, TSNE plots.

References:

- The Visual Display of Quantitative Information (2nd Edition). E. Tufte. Graphics Press, 2001.
- Envisioning Information, E. Tufte. Graphics Press, 1990.
